The Influence of Scale and Climate on Post-Wildfire Hydrologic and Geomorphic Processes in British Columbia

Peter Jordan
British Columbia Forest Service
(Ministry of Forests, Lands & Natural Resource Operations)
Nelson, BC, Canada

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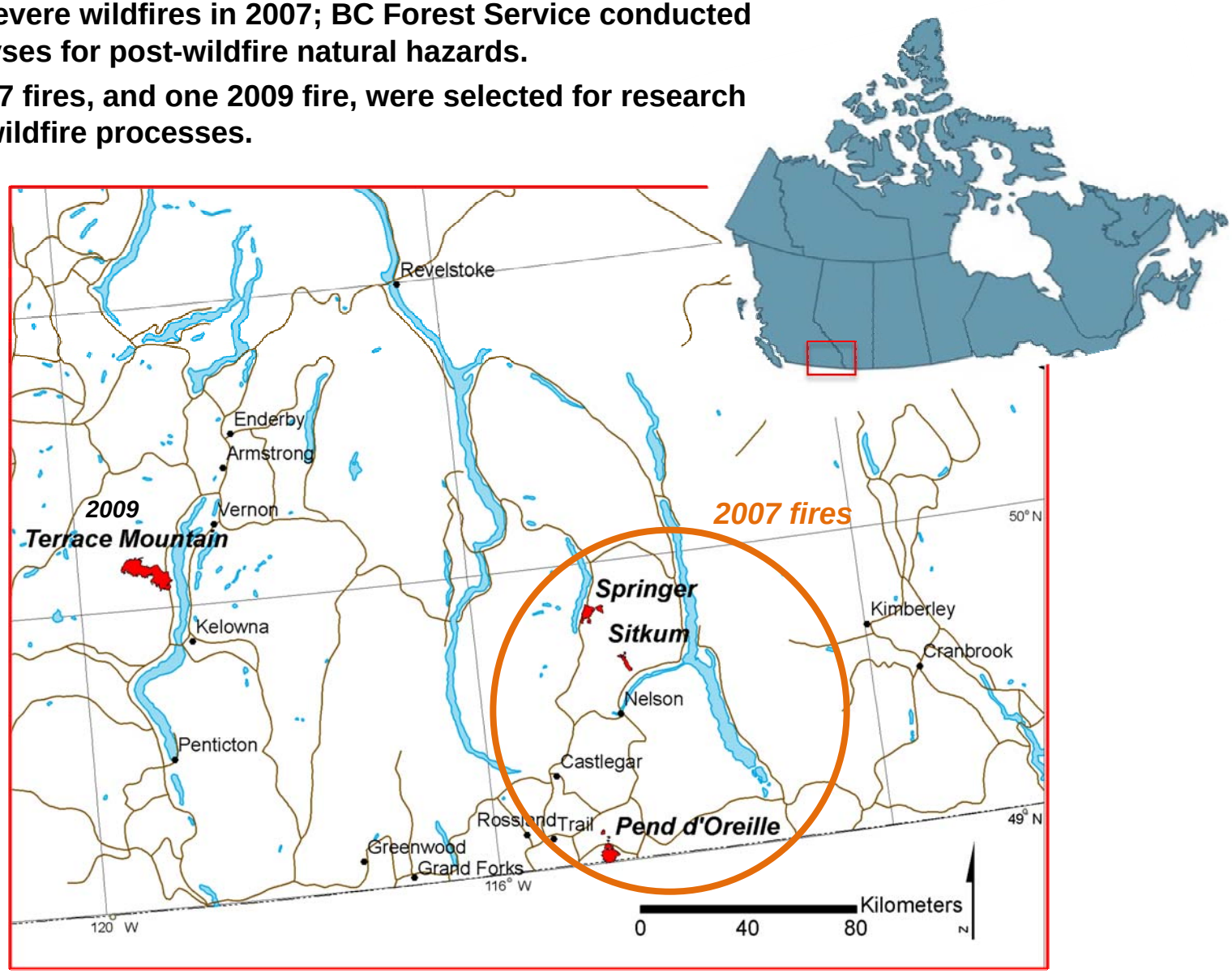
Introduction and Background:

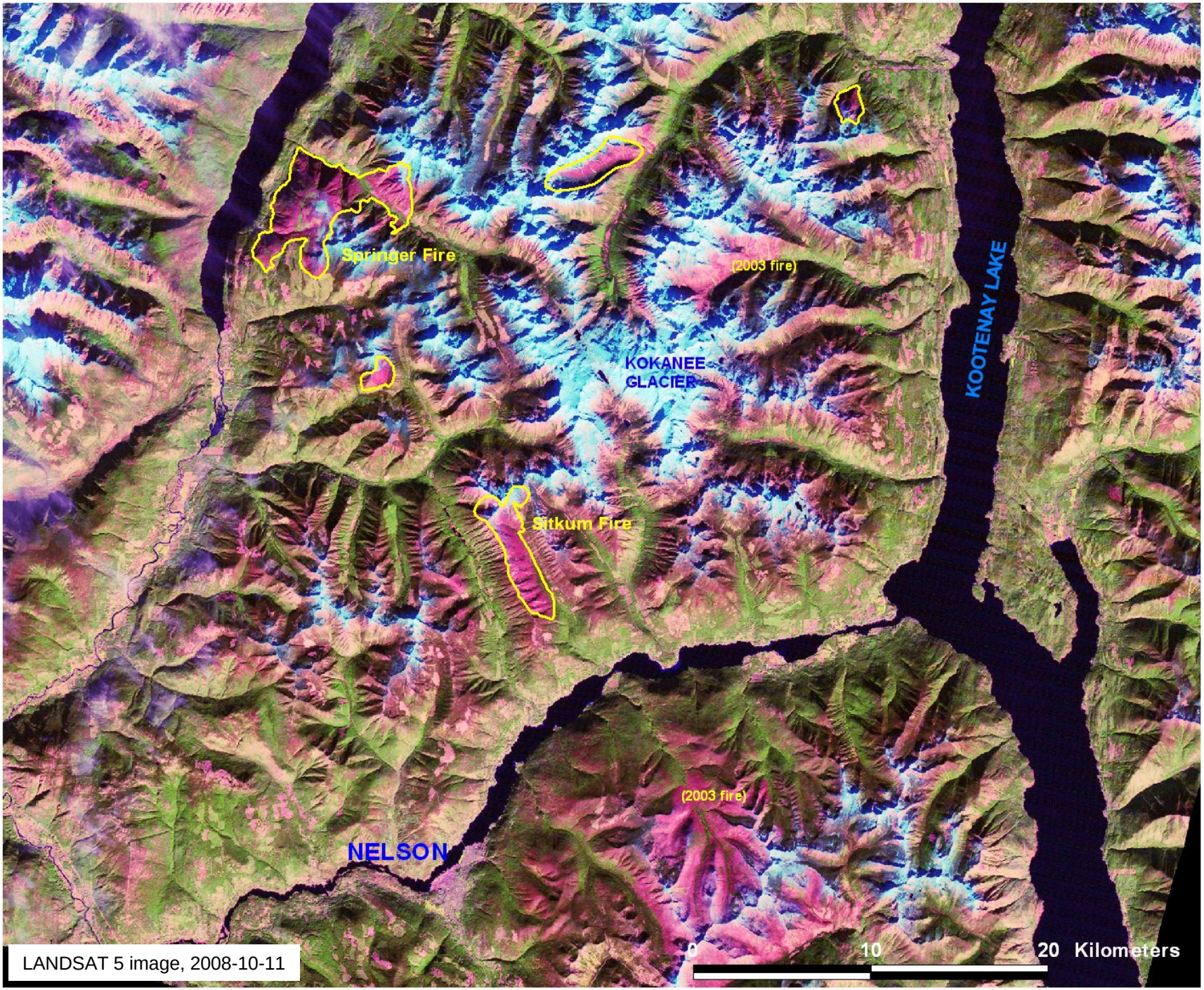
Post-wildfire natural hazards research in British Columbia

- Following the extreme fire season of 2003, several damaging debris flow and flood events occurred in British Columbia.
- The BC Forest Service developed a procedure to assess post-wildfire risks, and a research program to study the causes of such events.
- Objective of the research program: to obtain information which will help us better assess geomorphic and hydrologic hazards in interface areas.

Location: southeastern British Columbia in the Selkirk Mountains

- **Several severe wildfires in 2007; BC Forest Service conducted risk analyses for post-wildfire natural hazards.**
- **Three 2007 fires, and one 2009 fire, were selected for research on post-wildfire processes.**




Springer Fire
(2003 fire)
KOKANEE
GLACIER
KOOTENAY LAKE
Sitkum Fire
(2003 fire)
NELSON
0
10
20 Kilometers
LANDSAT 5 image, 2008-10-11

Research installations on four fires (three 2007, one 2009)

Soil and weather: water repellency transects, rain gauges, soil moisture recording stations

Erosion plots: 40 silt fences on the 4 fires

Aerial straw mulching, treatment ...

control

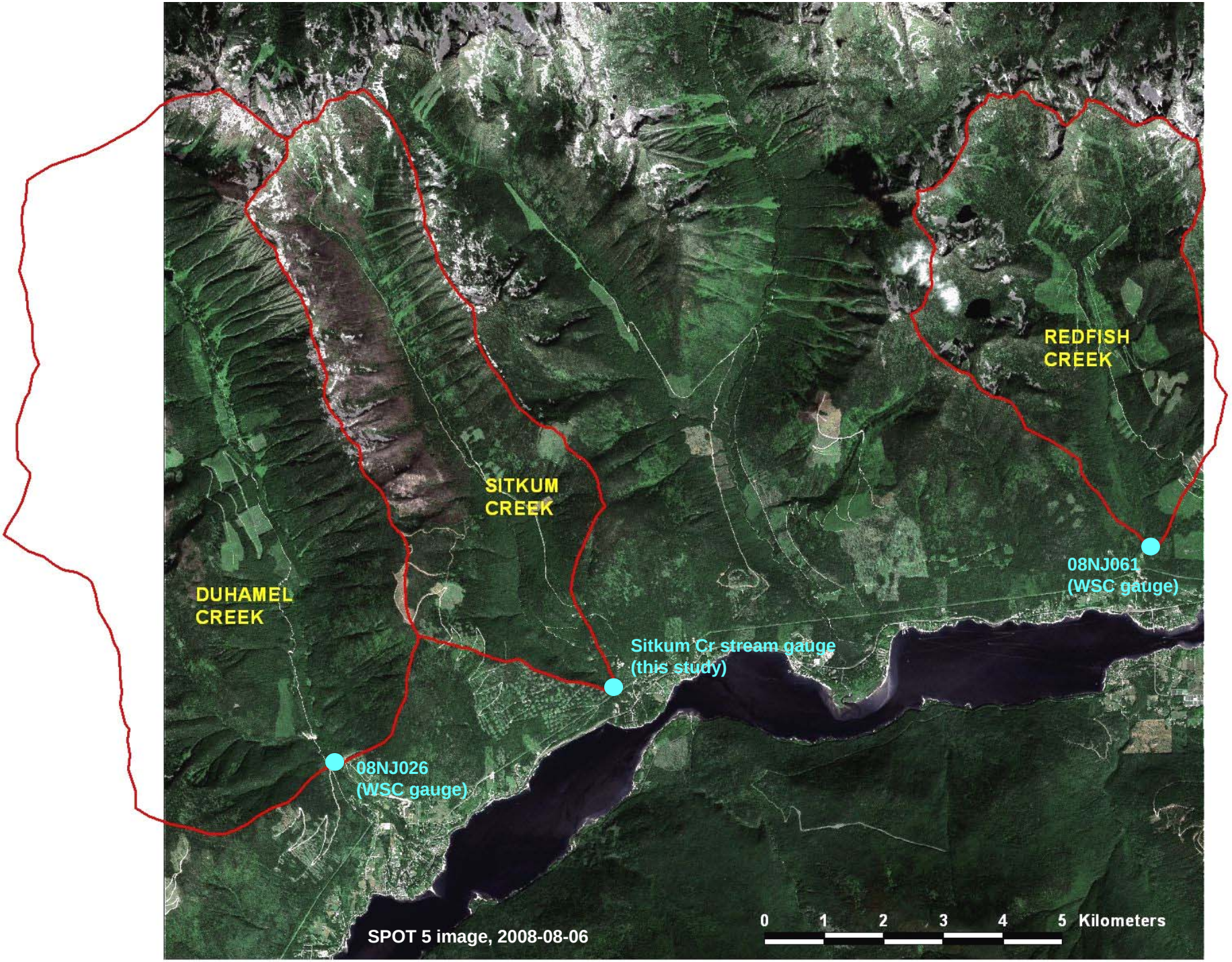
Moderate burn severity

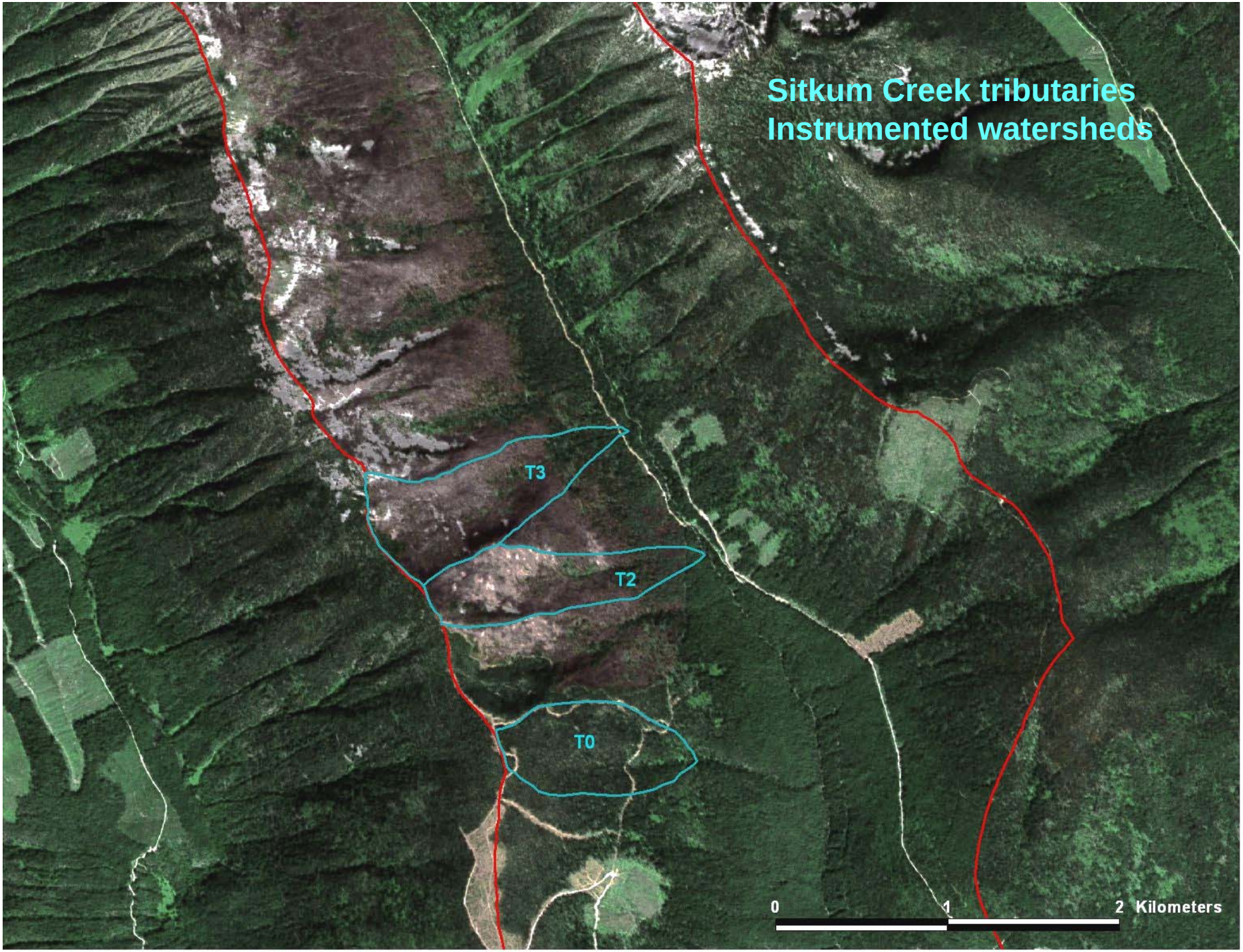
High burn severity

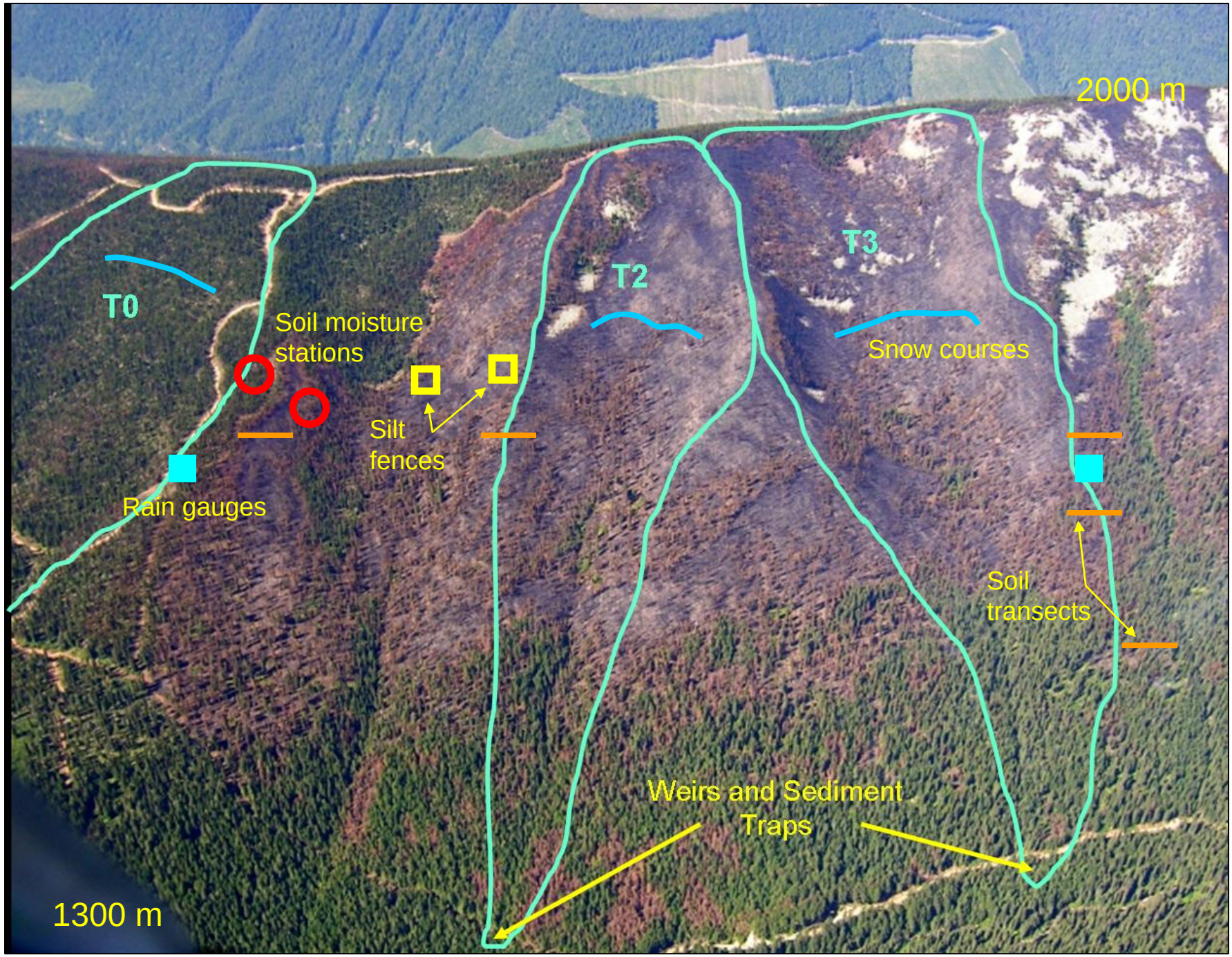
Summary of average annual sediment yield, all silt fences, all fires
Sediment Yield (Mg/ha)
2.50
2.00
1.50
1.00
0.50
0.00
Control
Mulch
n = 7
11
15
20
12
17
12
17
0
1
2
3
Years after fire

Study area for catchment-scale measurements – Sitkum Fire, July-August 2007

- The fire burned 39% of the 27 km^2 watershed
- Mean precipitation – ~1300 mm, mostly snow
- Snow-free season averages 4 to 5 months
- Elevation – 1400 to 2200 m
- Soils – sandy loam, stony, derived from glacial till and granitic rocks
- Forests – mostly spruce, subalpine fir

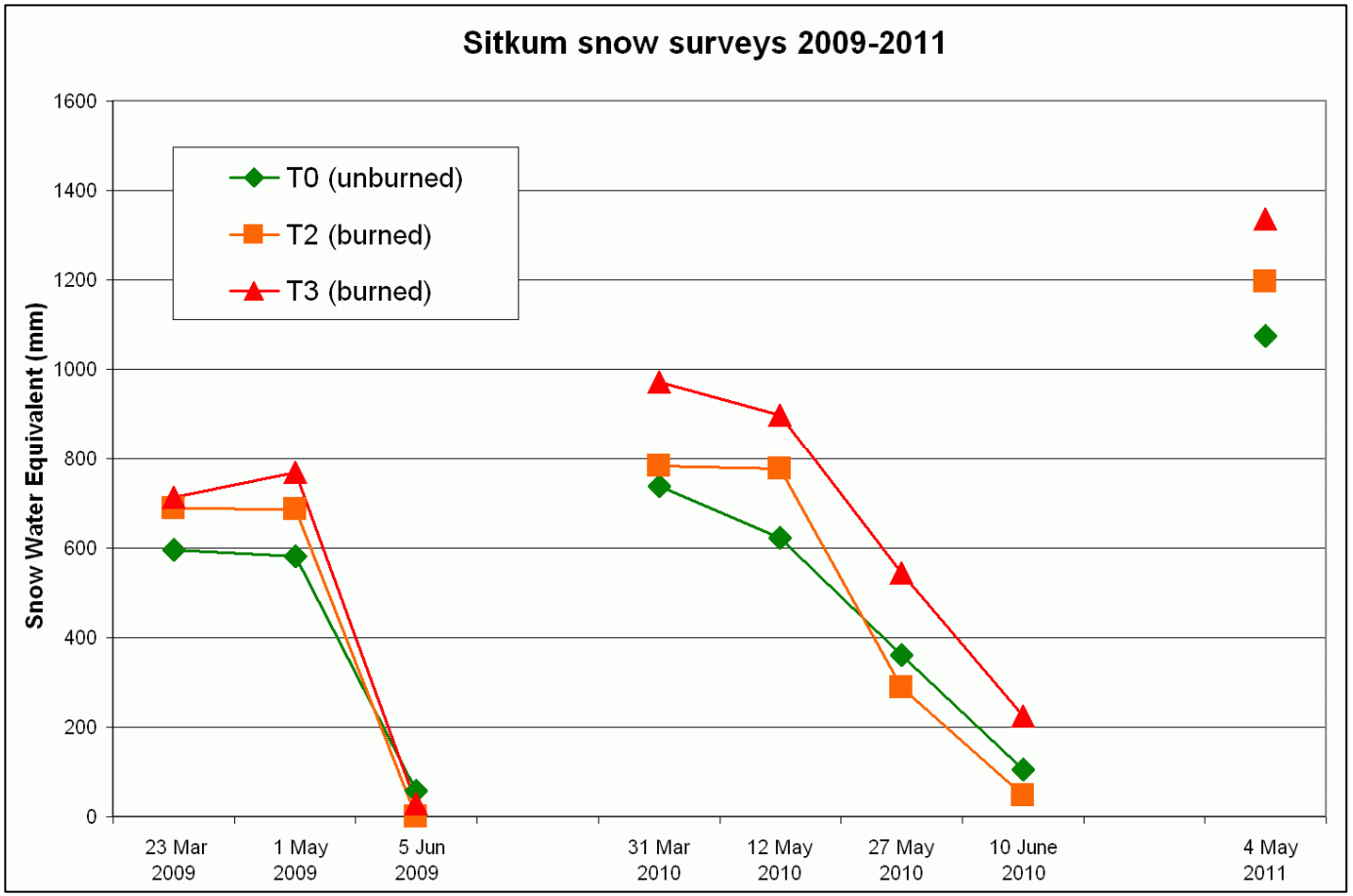

REDFISH
CREEK
SITKUM
CREEK
DUHAMEL
CREEK
08NJ061
(WSC gauge)
Sitkum Cr stream gauge
(this study)
08NJ026
(WSC gauge)
SPOT 5 image, 2008-08-06
0 1 2 3 4 5 Kilometers


Sitkum Creek tributaries
Instrumented watersheds
T3
T2
T0
0
1
2 Kilometers


2000 m
T0
T2
T3
Soil moisture stations
Silt fences
Snow courses
Rain gauges
Soil transects
Weirs and Sediment Traps
1300 m

Sitkum Creek: mean annual precipitation – about 1300 mm, of which 2/3 falls as snow.

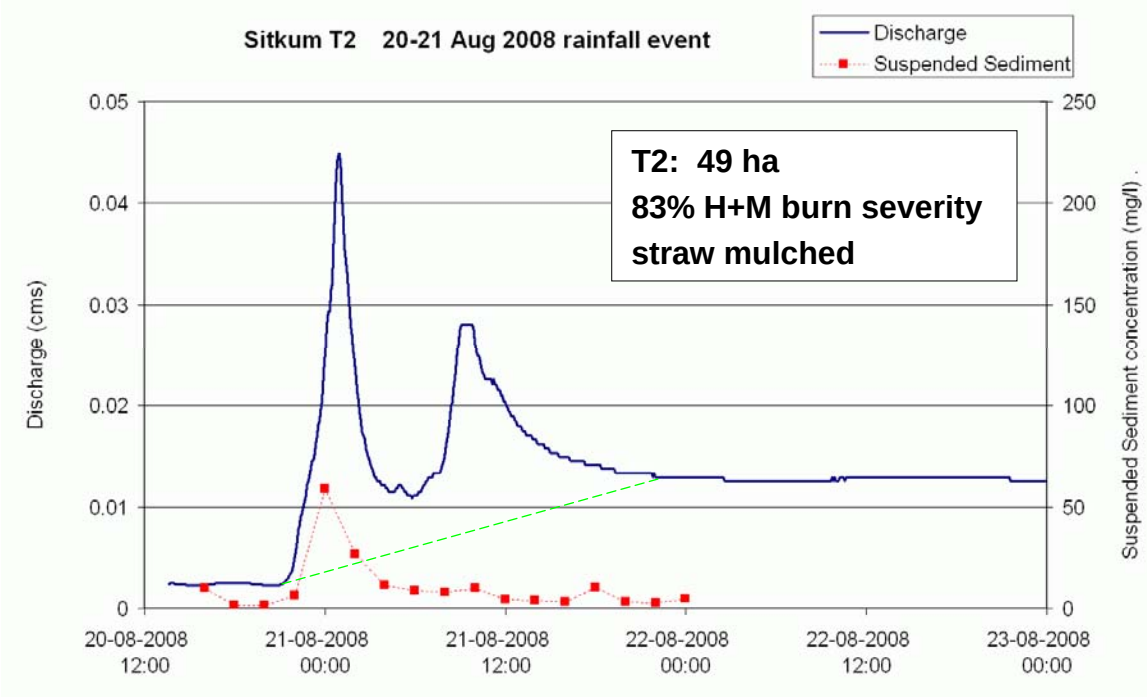
Snow surveys: Burned areas receive more snow accumulation (about 25% more), and it melts faster.

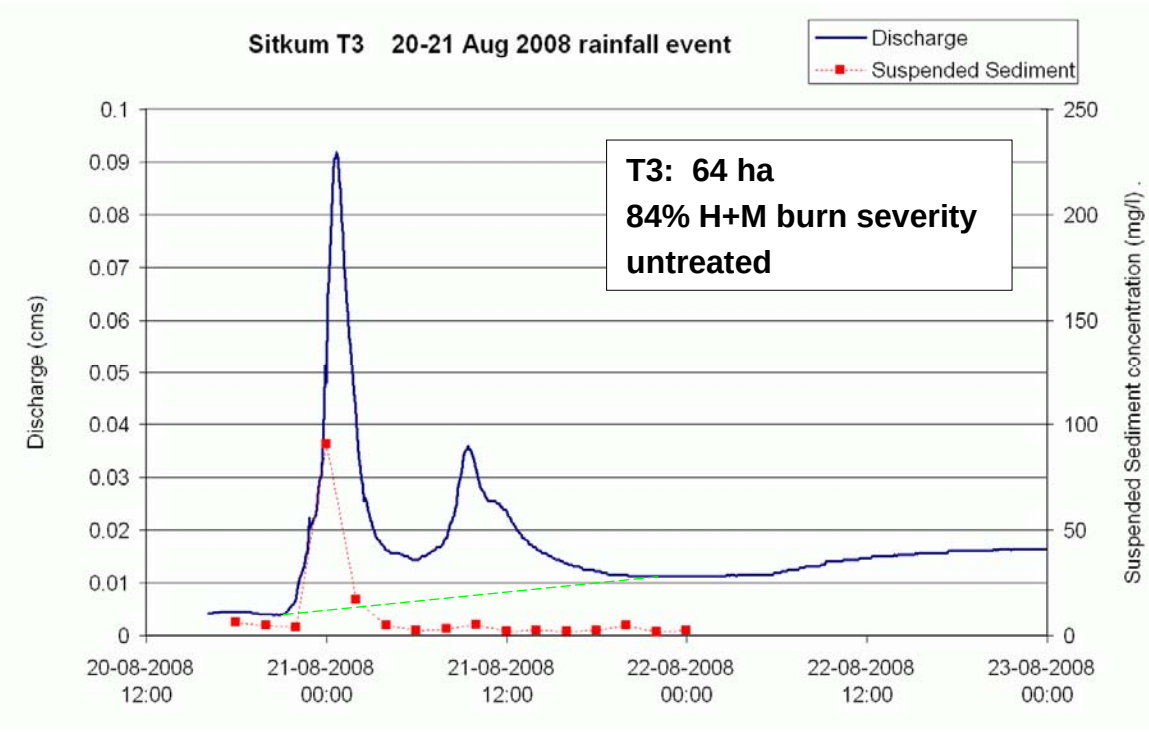


Instrumentation on each stream:

- Installed in August 2008
- V-notch weir, design capacity of 0.4 m^3/s
- Water level recorders
- ISCO pump sampler, normally programmed to take daily samples
- Operated May – October each year
- A log sediment trap was built above each weir, to catch coarse sediment
- These streams are potentially subject to debris flows, so the installation could be destroyed.

Sitkum T3 weir at peak flow

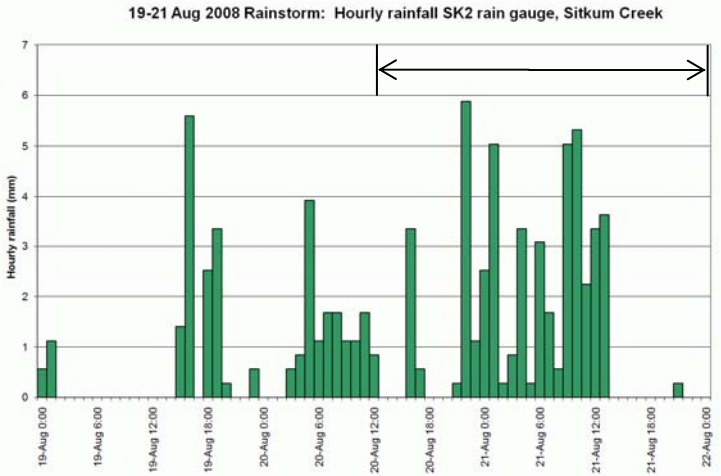


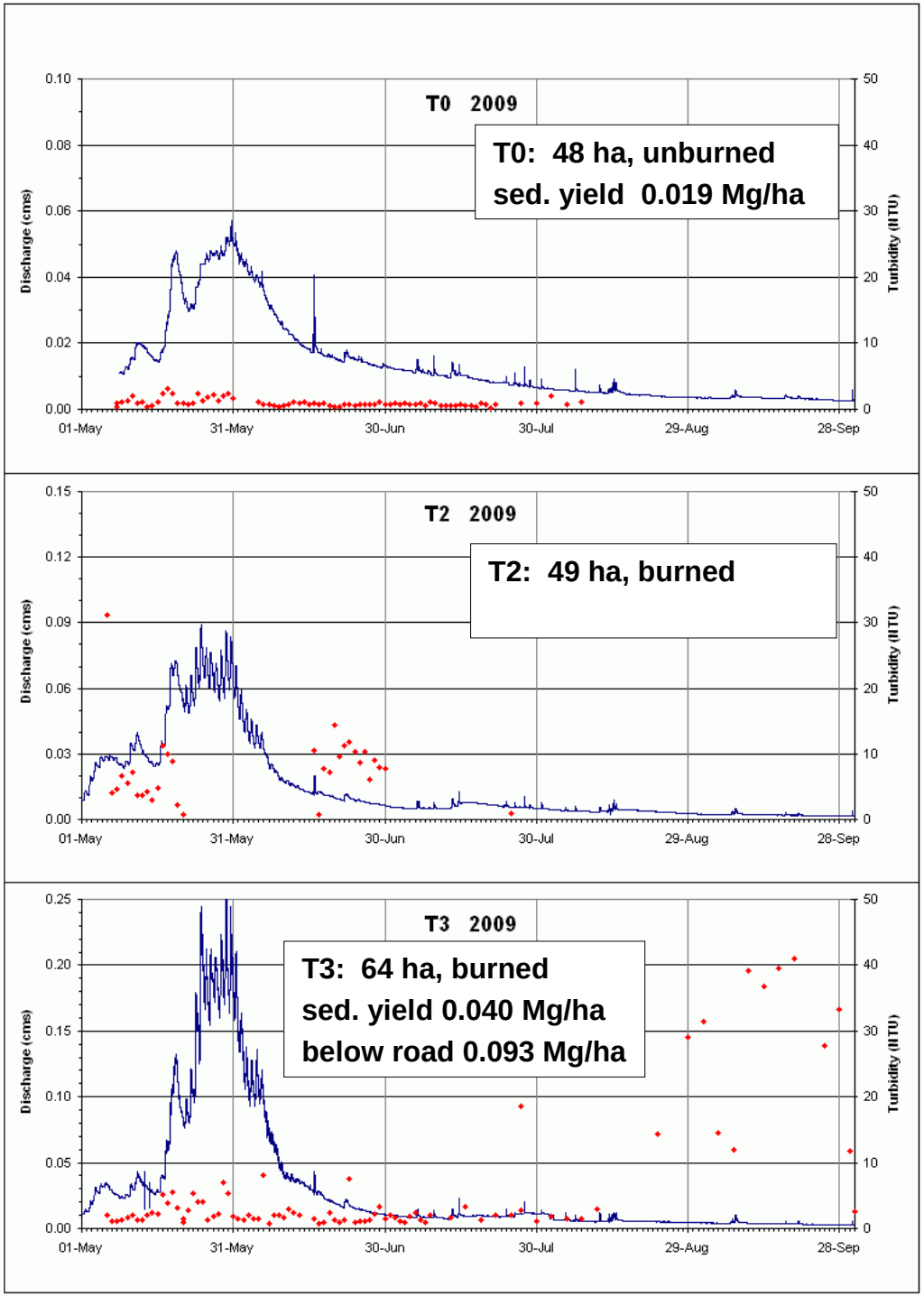


Results – watershed scale

Individual rainfall events:

- only one significant rainstorm in 2.5 seasons of measurement
- 19-21 Aug 2008, 75 mm rain in 3 days
- 24 hour rainfall was a 5-year return period event; shorter rainfall intensities were < 2 year return period
- storm runoff was about 2 mm, less than 3% of rainfall
- sediment yield:
  - T2 0.5 kg/ha = 0.0005 Mg/ha
  - T3 0.8 kg/ha = 0.0008 Mg/ha
- these yields are in the order of 1000 times less than the site-scale silt fence plots (assuming that most plot erosion was during this rainstorm)

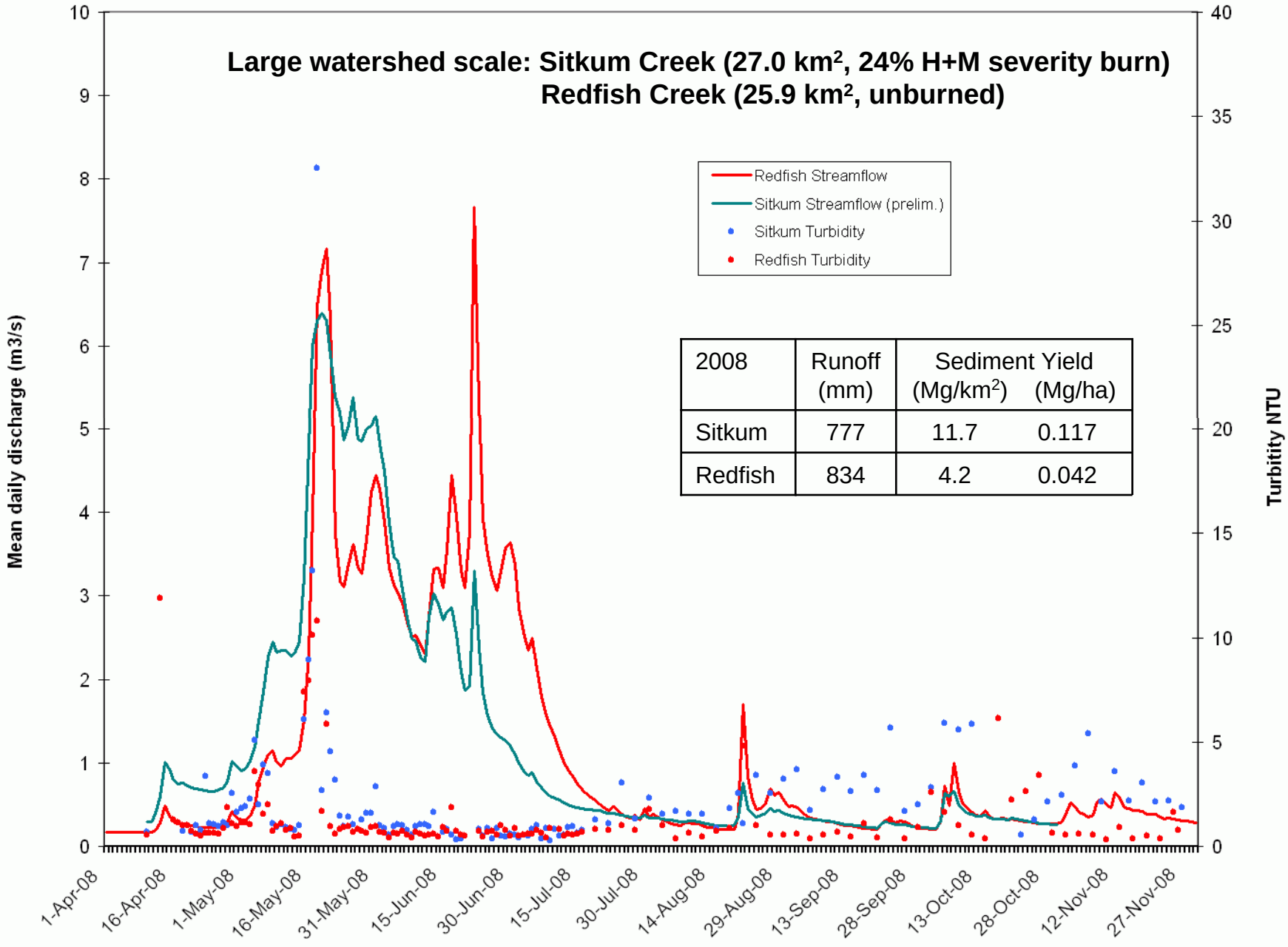




Watershed scale results for 2009, annual basis (year 2)

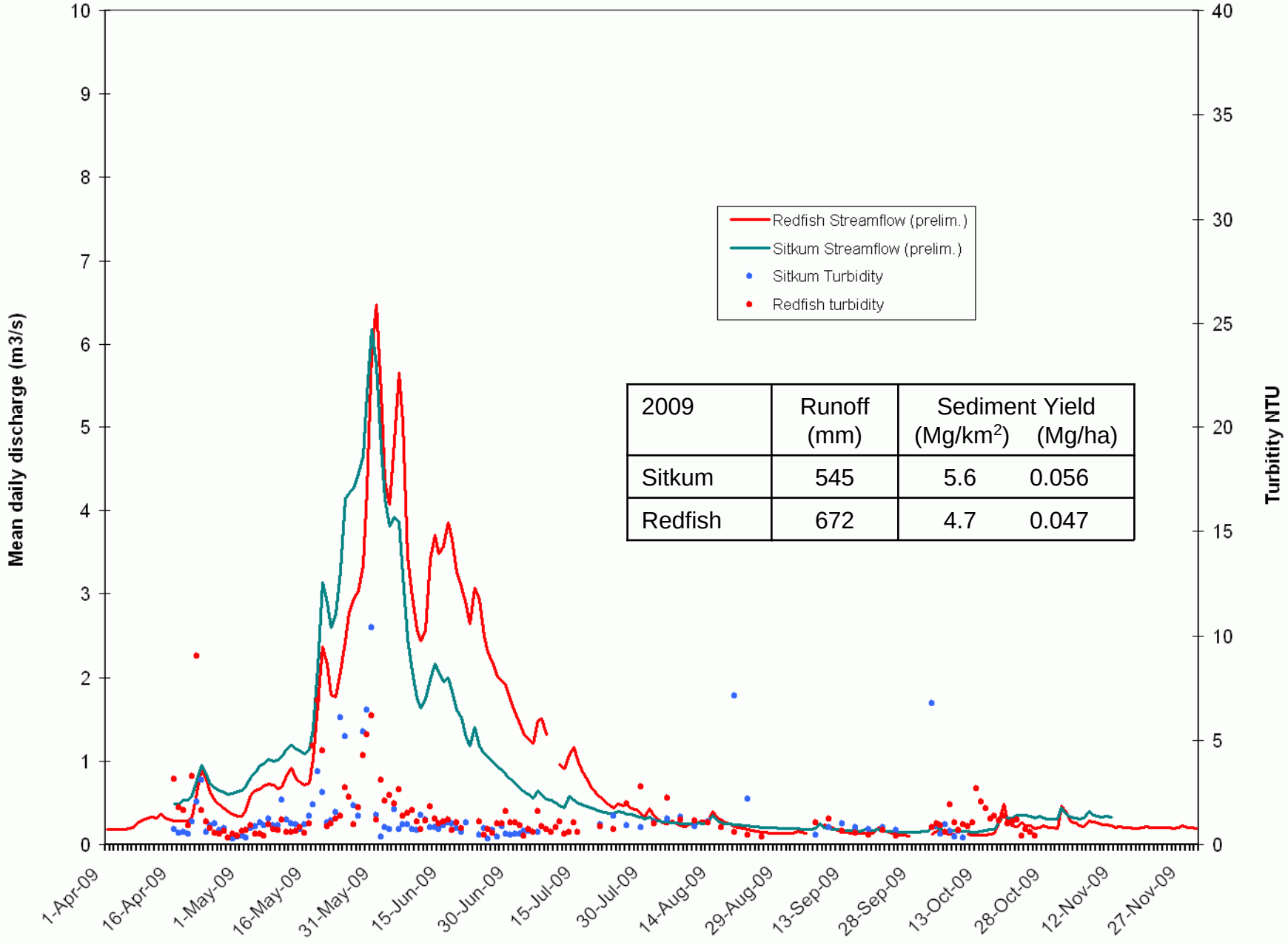
- There were no significant rainstorms in the summer of 2009.
- T0 (unburned) – less diurnal variation during snowmelt; slower recession after snowmelt.
- T2 and T3 – more rapid snowmelt, higher total water yield.
- T2 and T3 have significantly higher turbidity (a measure of suspended sediment) than T0.
- Local factors confound interpretation of sediment results – organic debris in T2, logging and road in T3 catchment.
- Caution must be applied in drawing conclusions – there are no pre-fire data, and there may be unknown differences in pre-fire hydrologic response between the watersheds.
- 2010 and 2011 – similar results, no rainstorms, similar sediment yield in T2 and T3

Large Watersheds - Redfish & Sitkum comparison 2008 (year 1)

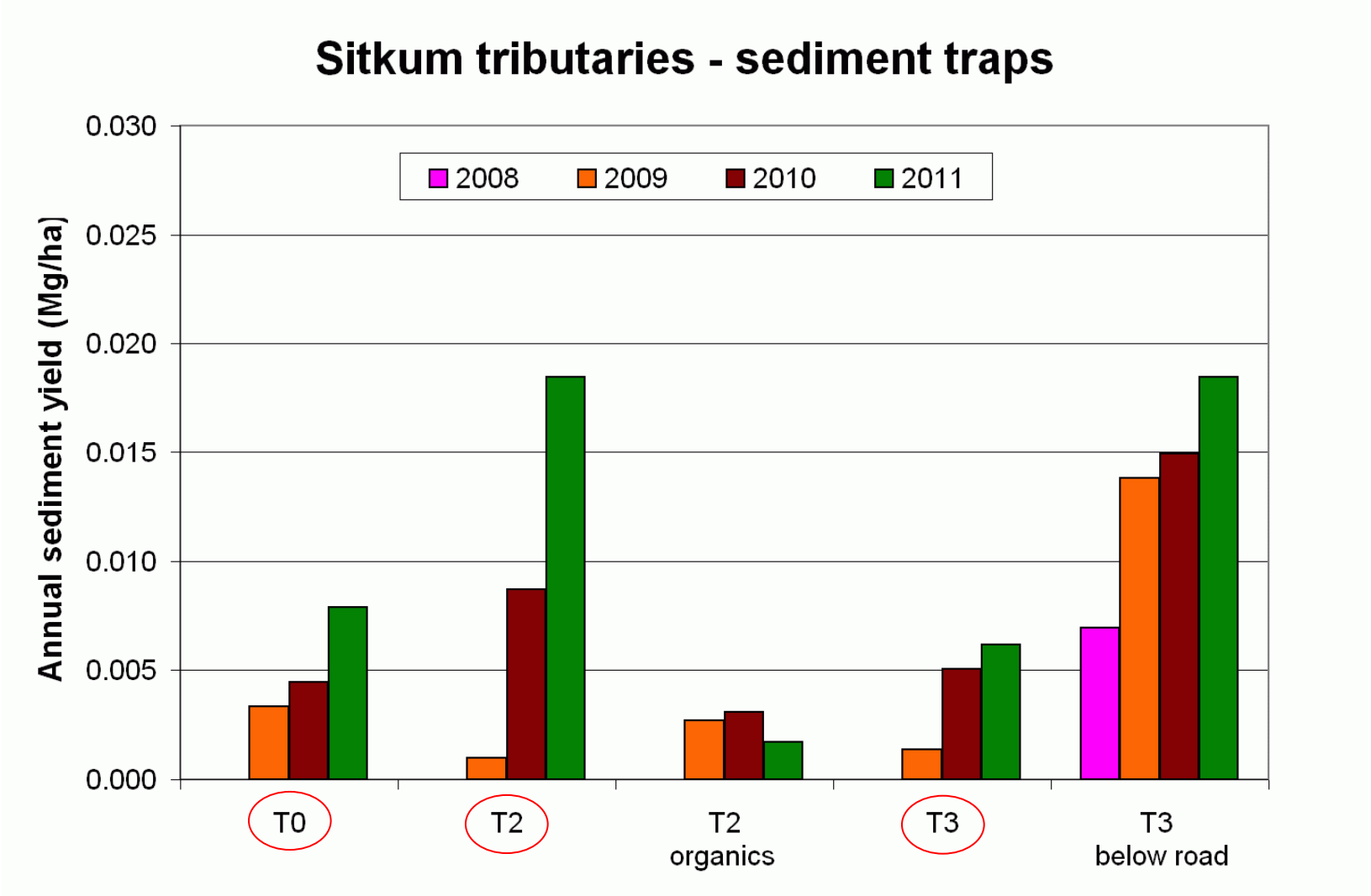


2008	Runoff (mm)	Sediment Yield (Mg/km²)	(Mg/ha)
Sitkum	777	11.7	0.117
Redfish	834	4.2	0.042

Large Watersheds - Redfish & Sitkum comparison 2009 (year 2)



2009	Runoff (mm)	Sediment Yield (Mg/km^2)	(Mg/ha)
Sitkum	545	5.6	0.056
Redfish	672	4.7	0.047



Total bedload yield for the 2nd, 3rd, and 4th years after the fire – roughly 1/10 to 1/5 the suspended sediment yield.

Increasing yield each year is mainly due to snowmelt runoff, which was low in 2009, greater in 2010, and greatest in 2011.

Traps were installed in summer 2008 (year 1), so bedload yield in the spring runoff of 2008 was not measured.

Watershed scale sediment yields are several orders of magnitude (10^2 to 10^4) lower than plot scale sediment yields. **Why?**

1. Many areas of apparently high soil burn severity have features which allow infiltration and trapping of eroded sediment.

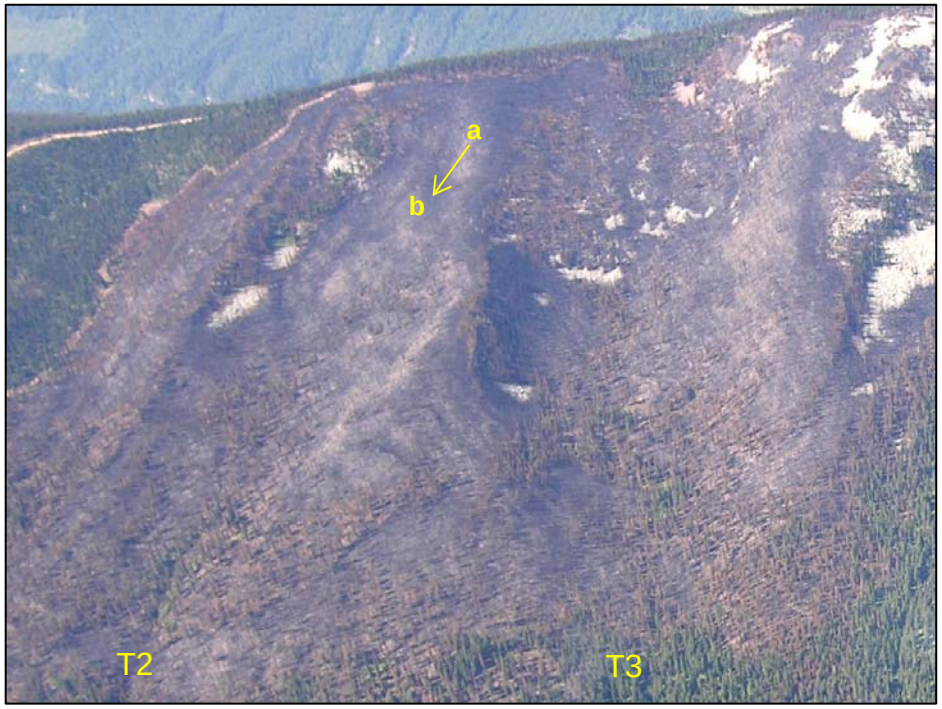
Root holes and stumps

Rocky areas

Rotten logs embedded in the soil

We tend to not select these areas for our plot-scale experiments.

2. Intermediate storage – Most eroded sediment moves only a short distance downslope before being caught behind an obstruction, or by gentle slopes. (low connectivity between slopes and channels)



Sitkum Creek – U-shaped bowls (a legacy of glaciation) have gently-sloping land where sediment is deposited between steep slopes and the channel

a

b

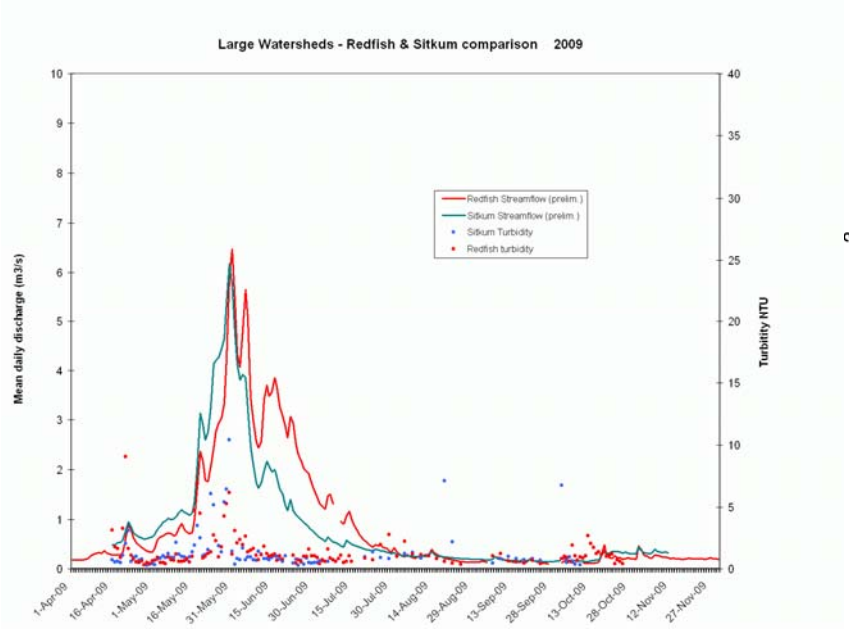
same place,
3 years later

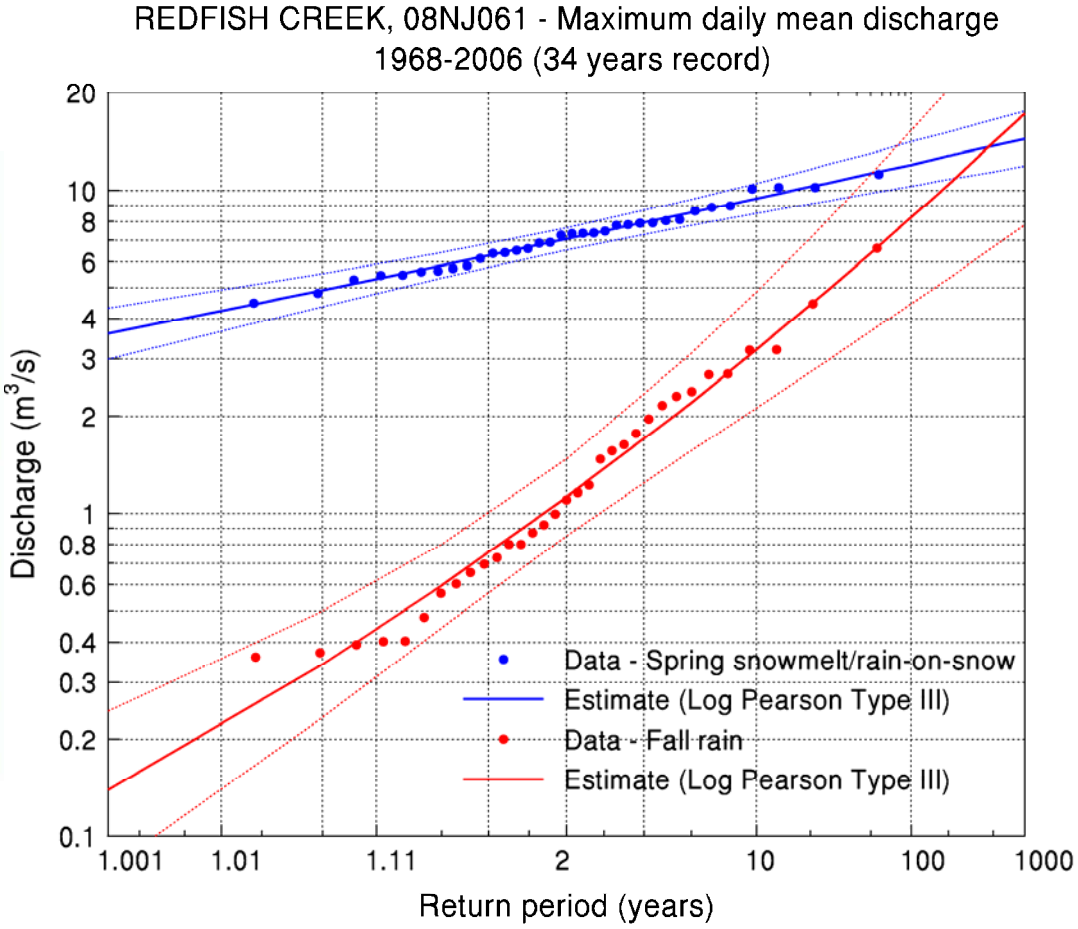
3. Many small stream channels have limited capacity to convey coarse sediment.
   – controlled by lag boulders (especially in granitic terrain) and large organic debris
   – these streams typically have extremely low sediment yields, except when they experience a debris flow (every few decades or centuries)
   – dense riparian vegetation can trap sediment from adjacent slopes

Sitkum T2 channel below burn

Sitkum T3 channel in burn, 3 years after

4. Climate and hydrology:
   – rainfall intensities are low compared with more southerly latitudes
     (although similar to the US intermontane [sub-Pacific] region)
   – the season of snow cover is 6 to 8 months, and most precipitation falls as snow
   – the annual hydrograph is dominated by snowmelt; only an exceptional post-fire rainstorm can produce a discharge comparable to peak snowmelt.

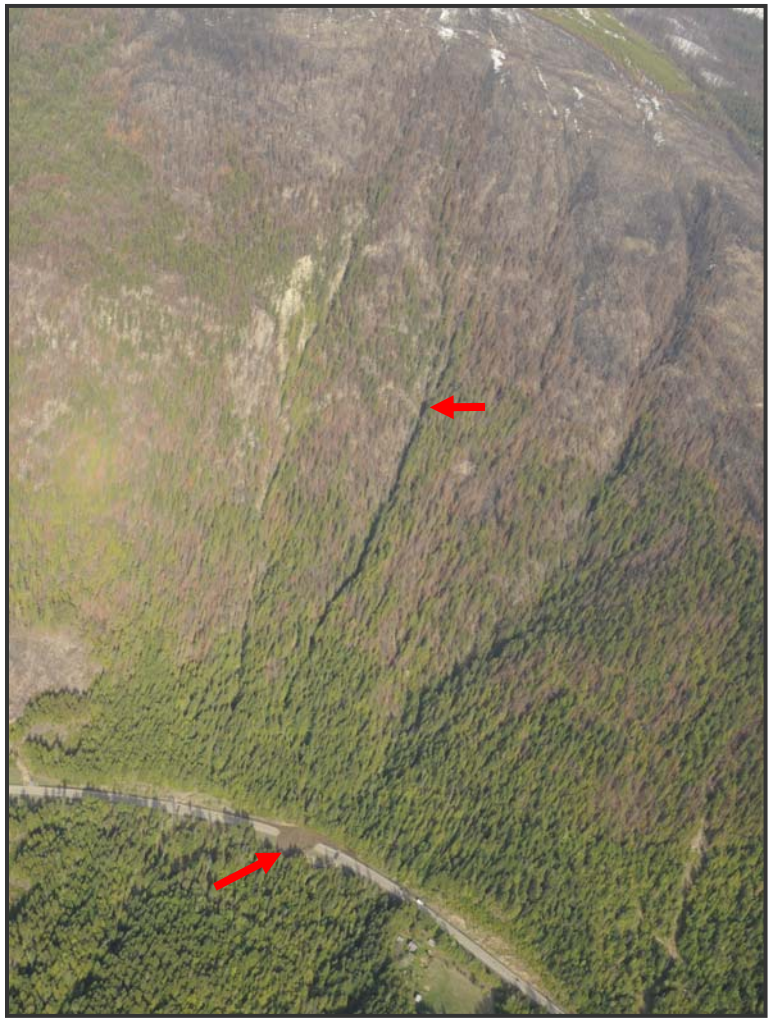




Post-wildfire debris flows:

(Springer fire, 20 km NW of Sitkum)

- 8 significant debris flows since 2007
- Effective sediment yields 10 – 100 Mg/ha
- Most initiated in the channel; almost all sediment came from channel incision



Enterprise Creek tributary gullies, 2007, 2008, and 2009

Middle Van Tuyl Creek, 2008

Summary: Typical post-wildfire annual sediment yields

(very approximate, order of magnitude; applicable to this study area only)

(Caution: only 4 years of record; no unusually large or intense rainstorms have occurred)

- Source area (selected small plots, high soil burn severity): **1 Mg/ha**
- Watershed scale, suspended sediment and bedload trap measurements (if no large-scale mass movement occurs): **0.01 – 0.1 Mg/ha**
- Debris flows in small steep catchments: **10 – 100 Mg/ha** (most sediment comes from channel incision, not from burned area)

Casual observations and anecdotal information from many fires in the southern interior of BC indicate that:

- significant surface erosion, and transport of eroded sediment by small streams, is limited to a few small areas
- water quality impacts are minimal in most fires
- in susceptible terrain, the hazard (likelihood of occurrence) of debris flows is greatly increased over pre-fire conditions.

Acknowledgements:
Ashley Covert and Amy O'Neill
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Pete Robichaud, US Forest Service

Thank you !